Primordial Dirac Leptogenesis

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Max-Planck-Institut für Kernphysik

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MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

IMPRS
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INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

Matter-antimatter asymmetry

- BBN and CMB measurements

$$\boxed{\eta_B = \frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 6.1 \times 10^{-10}}$$

[arXiv:1710.11129, 1807.06209]

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Need New Physics!

Majorana leptogenesis

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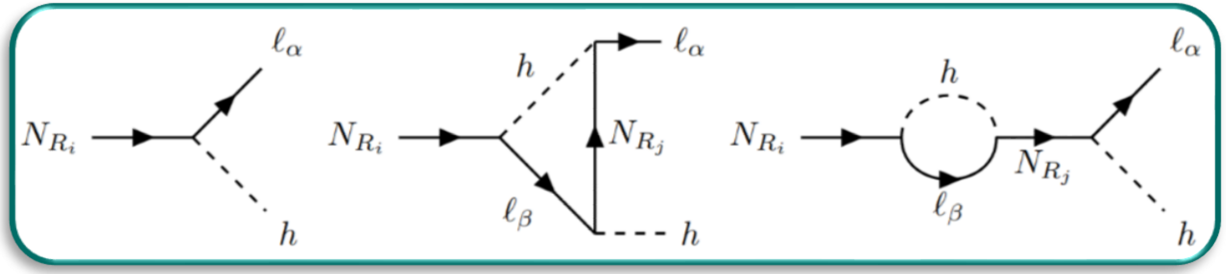

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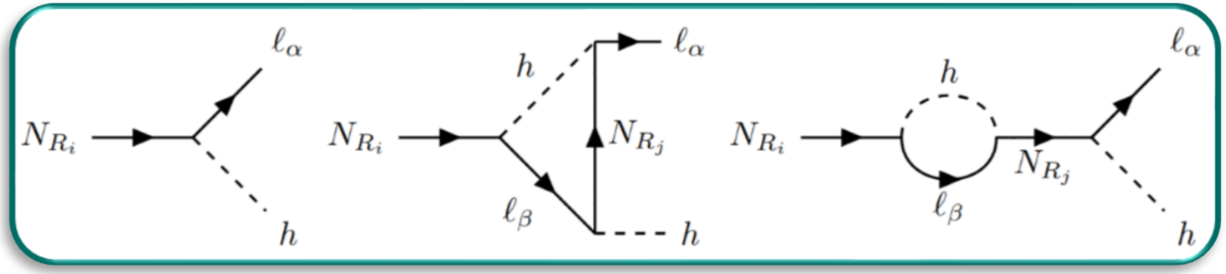

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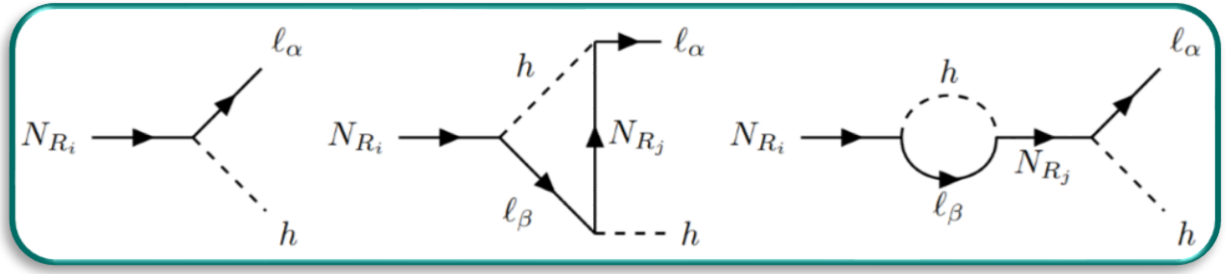

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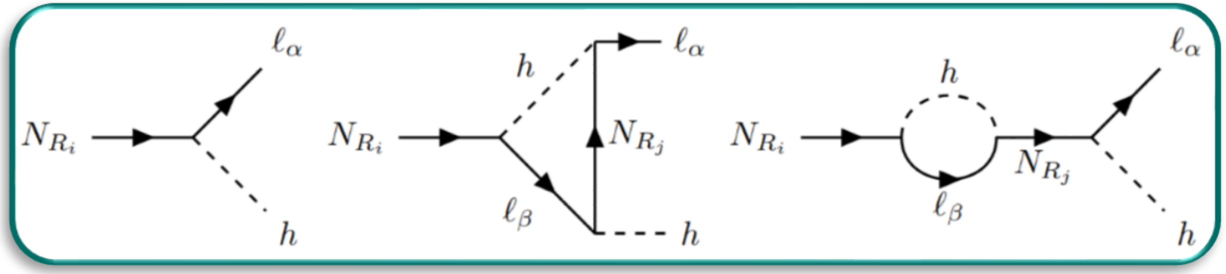

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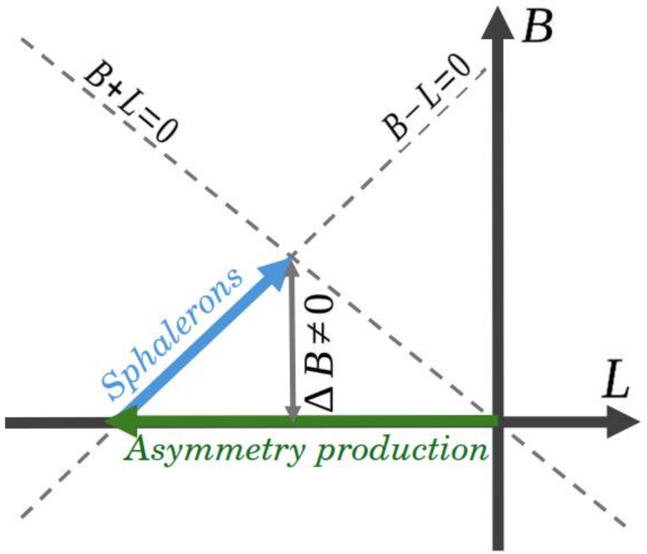

Dirac leptogenesis

K. Dick, M. Lindner, M. Ratz, and D. Wright [hep-ph/9907562]

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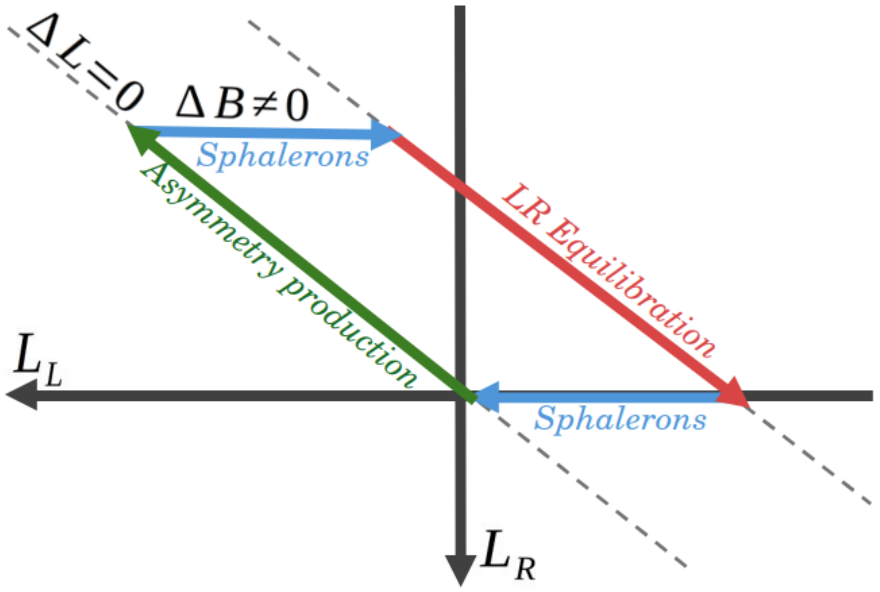

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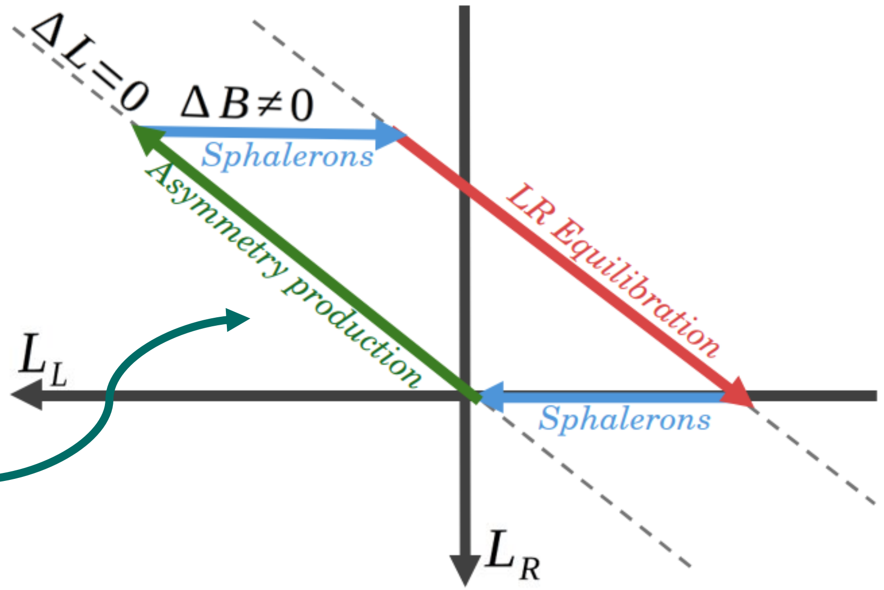
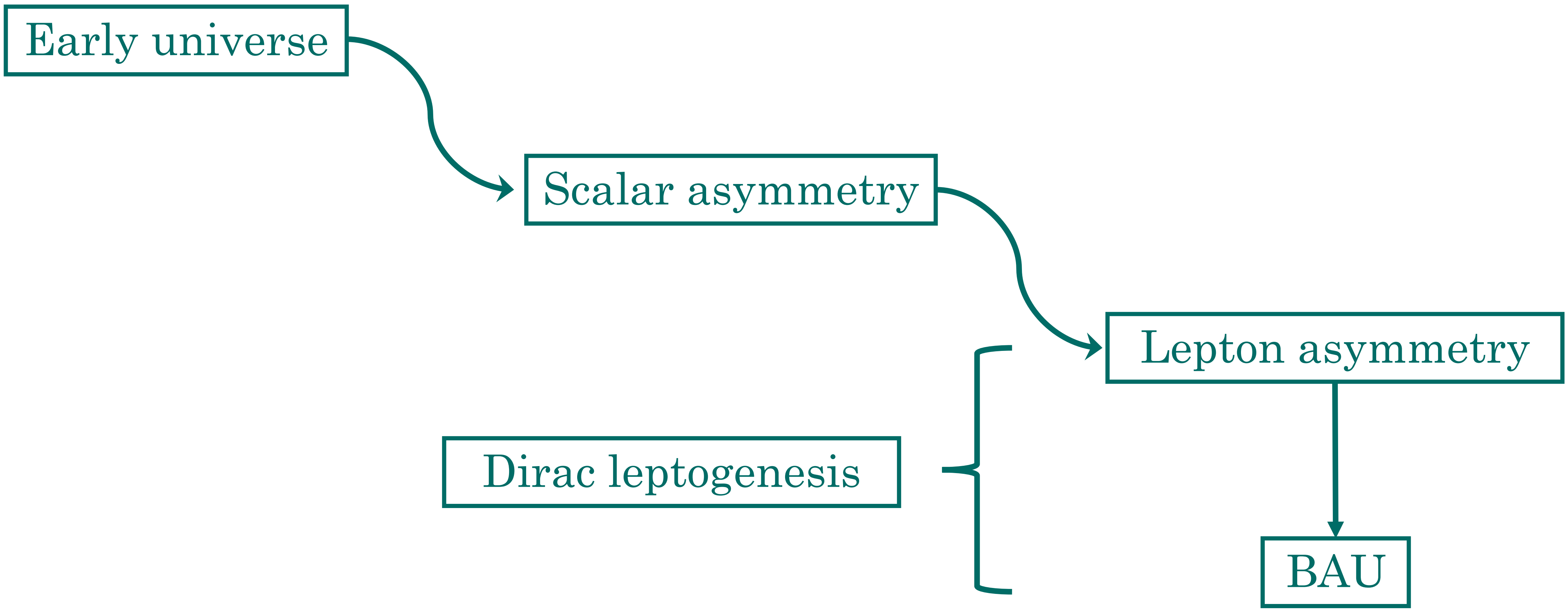


What sources the sequestered asymmetry?

BAU from scalar asymmetry



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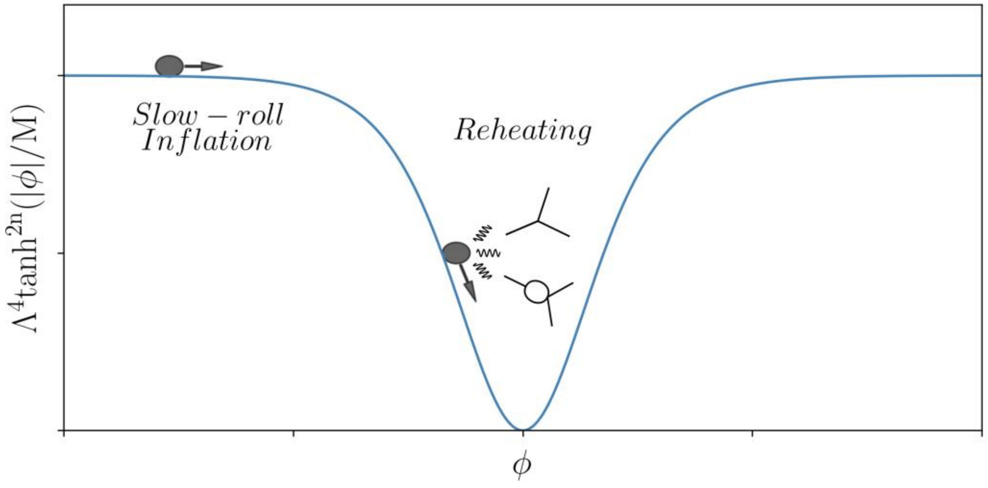

Minimal realization

G	ϕ	$\hat{h}$	ν_R
$\mathrm{SU}(2)_L$	1	2	1
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$$\boxed{\mathcal{L} \supset g_{h\phi} M_{Pl} \phi h^\dagger \hat{h} + \lambda_5 \left(h^\dagger \hat{h}\right)^2 + \mathrm{h.c.}}$$

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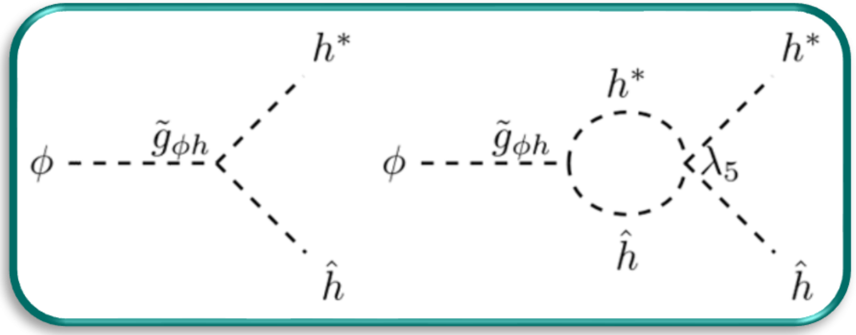
- An asymmetric scalar sector is obtained via the interference of decay diagrams (and their conjugates)



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- The scalar asymmetry is transferred to the leptonic sector via

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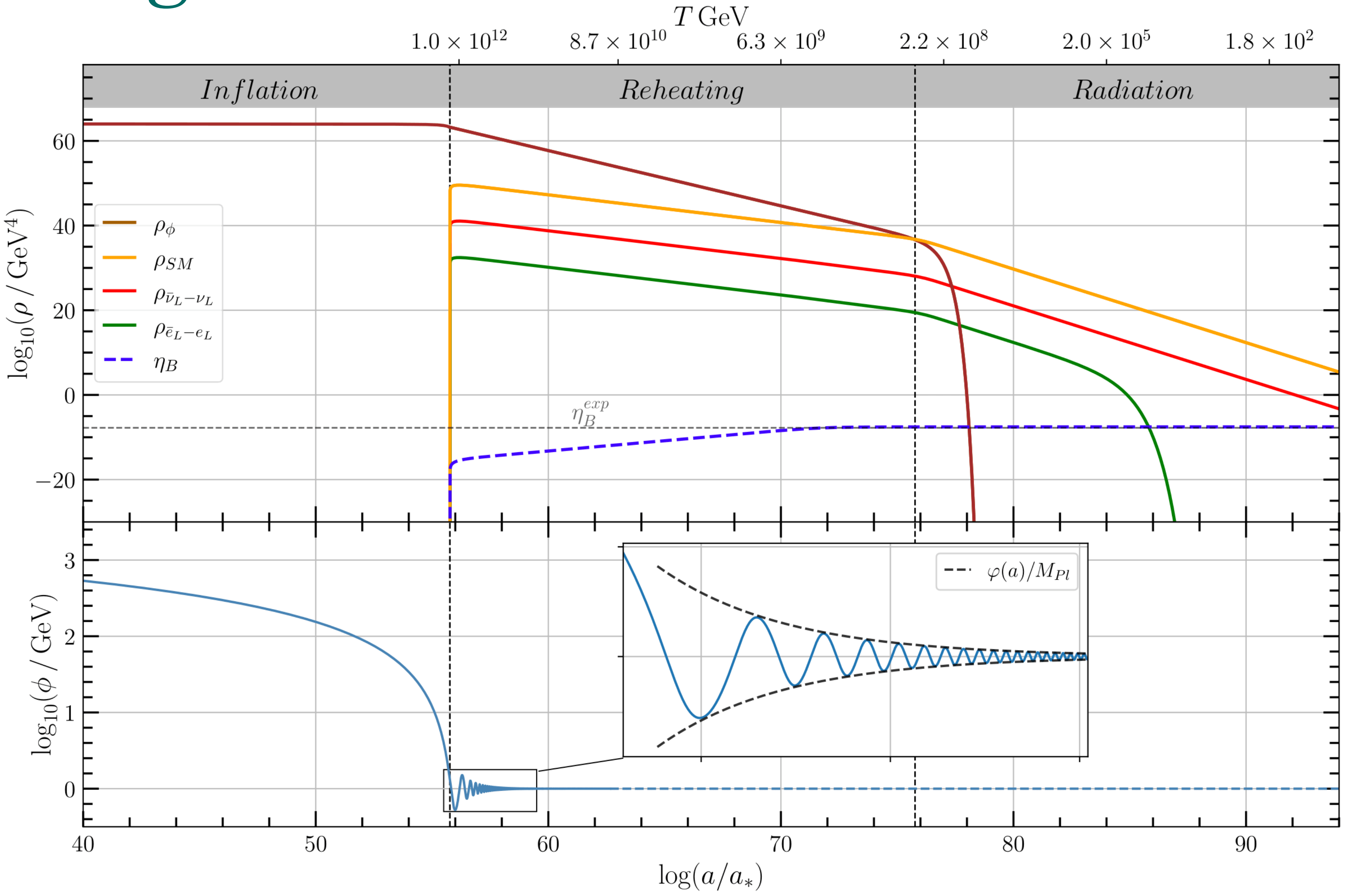
- If these are met, we get the following baryon asymmetry

$$\boxed{\eta_B = \frac{4(1+2N_f)}{9+14N_f}\frac{n_\nu - n_{\bar{\nu}}}{n_\gamma} \propto |\lambda_5| \cdot \arg(\lambda_5 \cdot g_{h\phi})}$$

Cosmological evolution



Summary and outlook

Inflation

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Satisfy constraints on cosmological parameters

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Inflation → (ϕ_e, ρ_{ϕ_e})

↑

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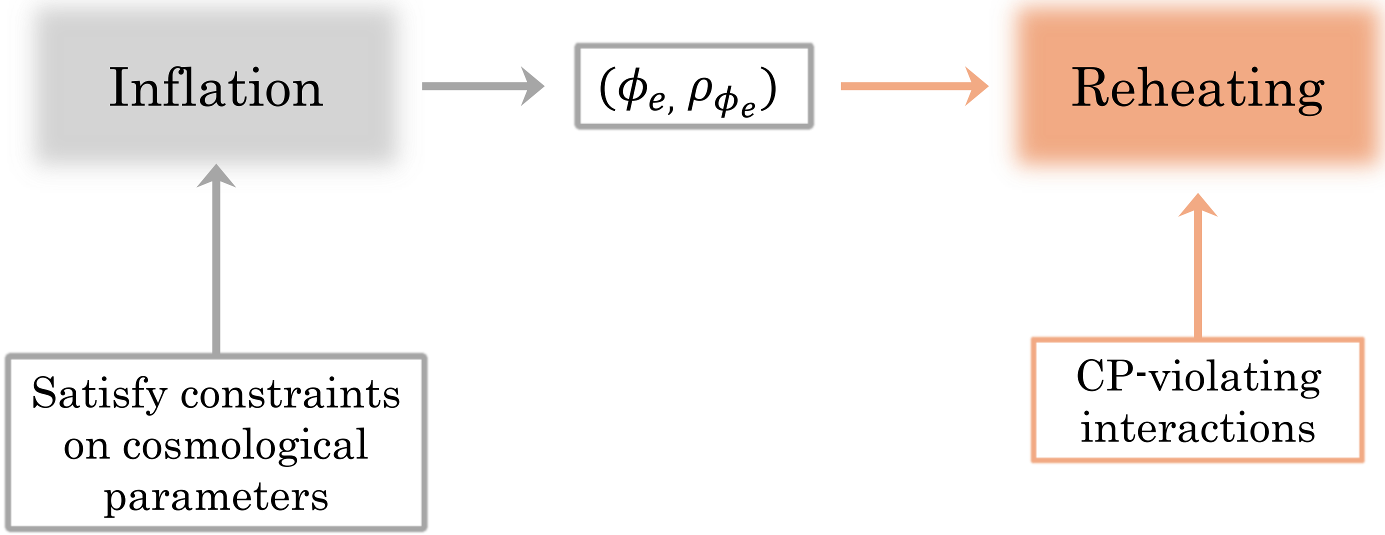

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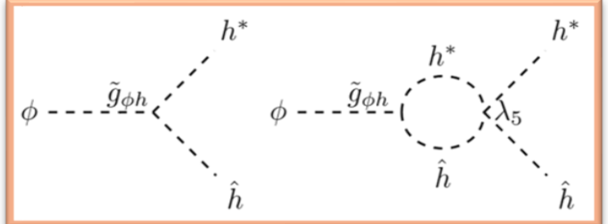

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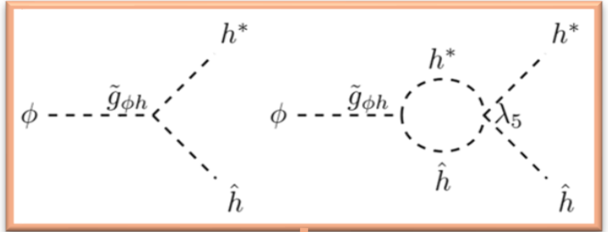
Inflation → (ϕ_e, ρ_{ϕ_e}) → Reheating → Asymmetric scalar sector

Satisfy constraints on cosmological parameters → Inflation

CP-violating interactions → Reheating



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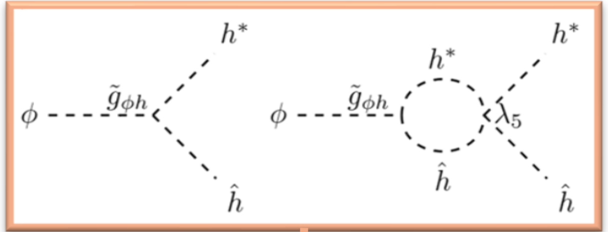

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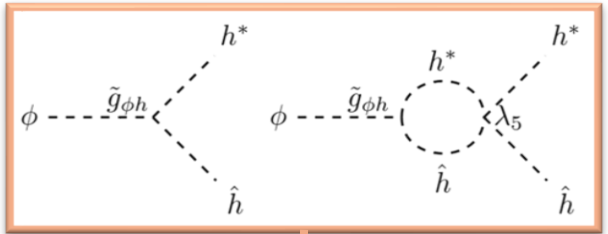

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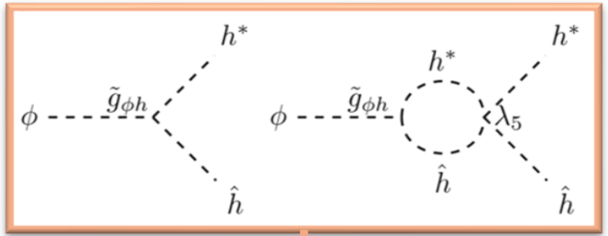

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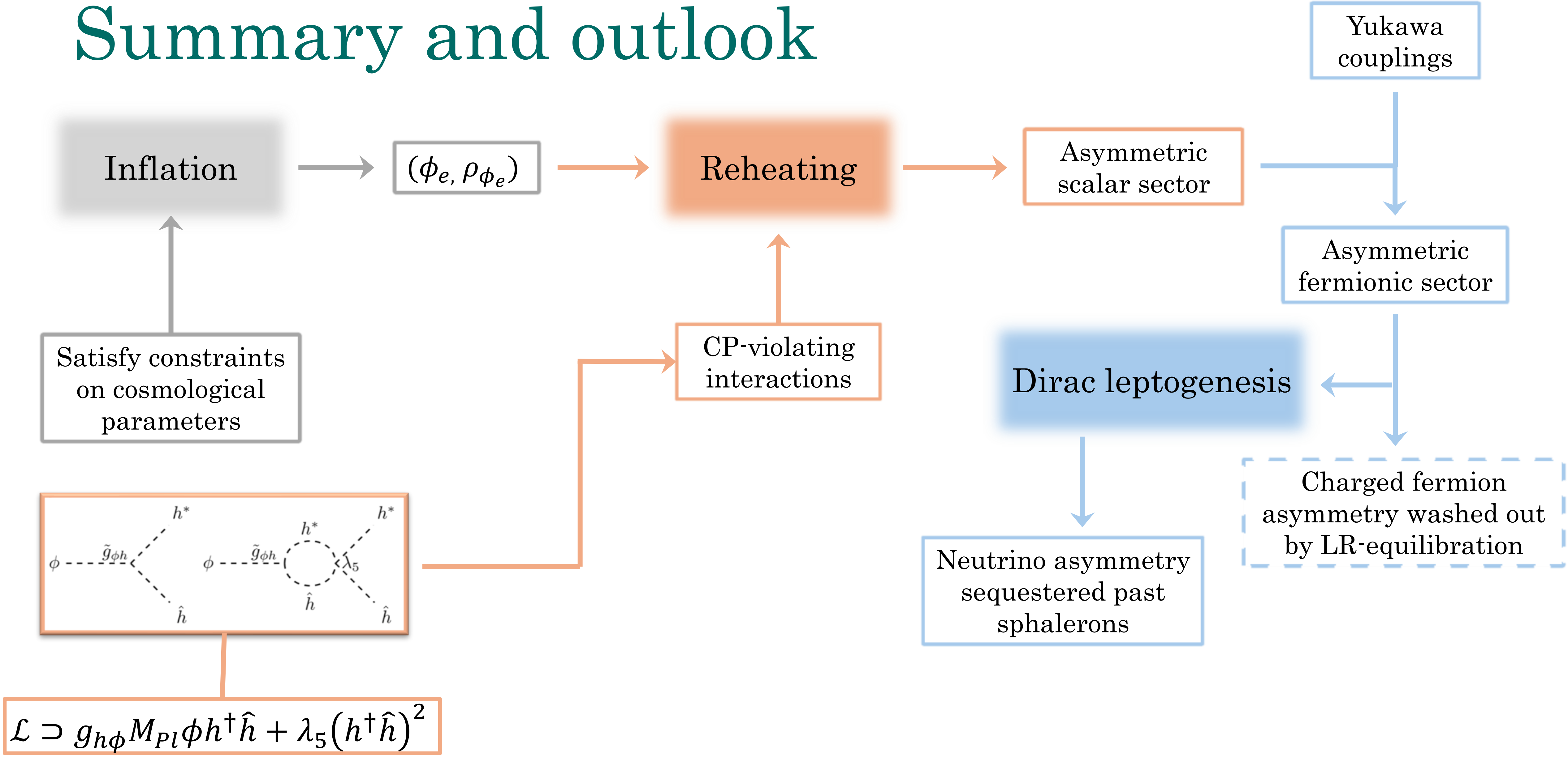

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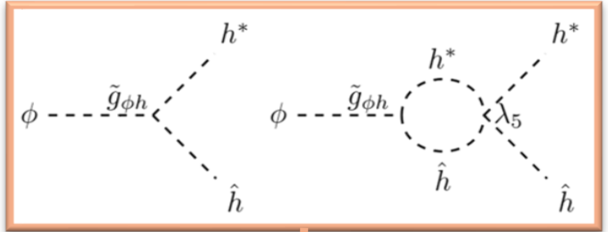

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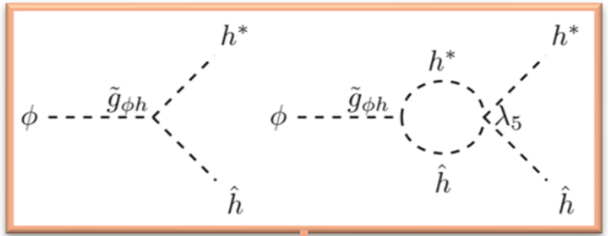

Neutrino asymmetry sequestered past sphalerons

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$\eta_B \propto |\lambda_5| \cdot \arg\left(\lambda_5 \cdot g_{h\phi}\right)$

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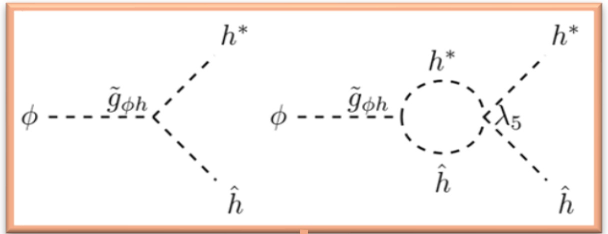

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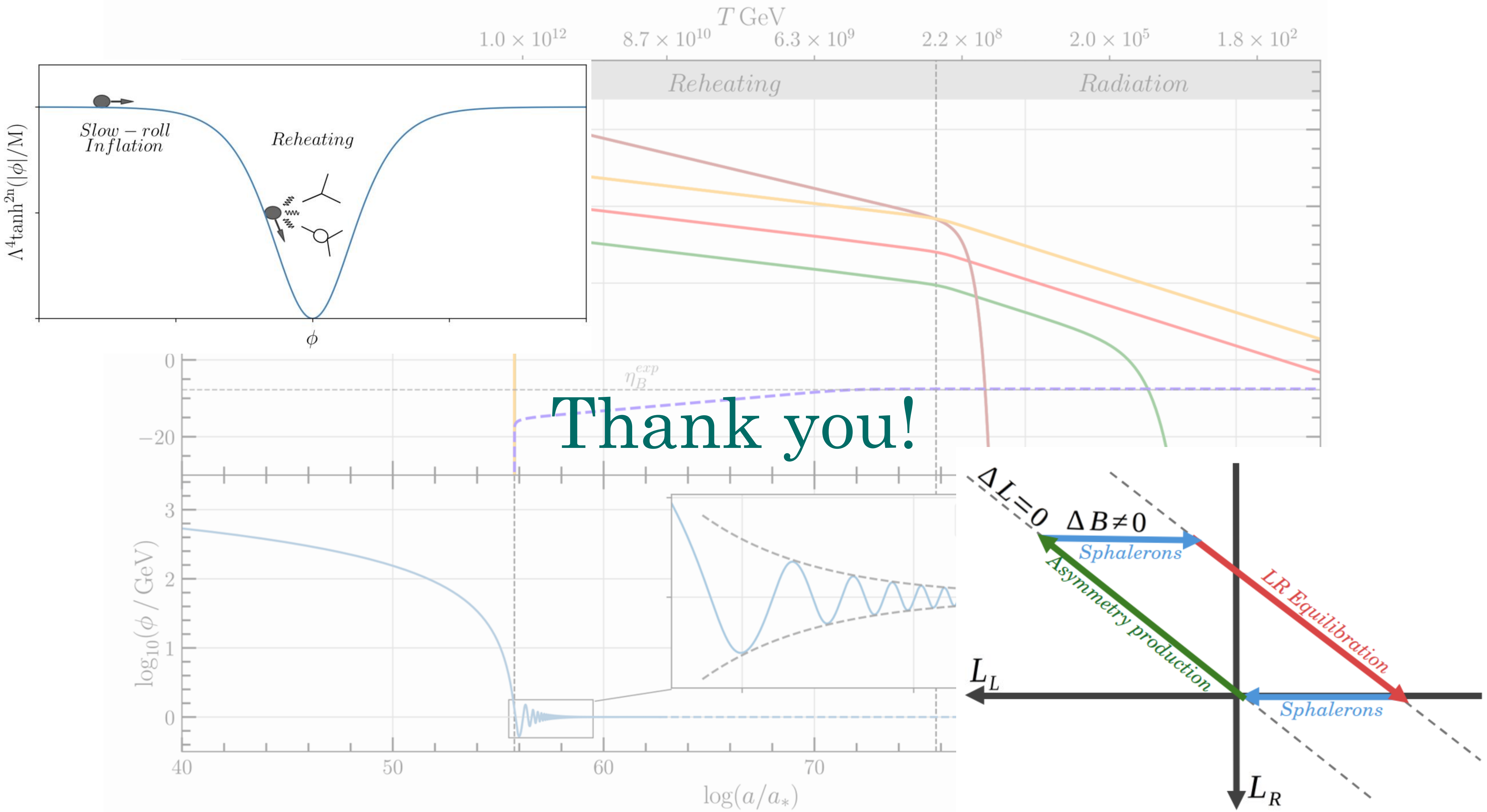
Testability?

$\eta_B \propto |\lambda_5| \cdot \arg(\lambda_5 \cdot g_{h\phi})$

Weak sphalerons $\Delta L_\nu \to \Delta B$

Thank you!



$\Lambda^4 \tanh^{2n}(|\phi|/M)$
Slow − roll Inflation
Reheating
ϕ
T GeV
1.0×10^{12}
8.7×10^{10}
6.3×10^{9}
2.2×10^{8}
2.0×10^{5}
1.8×10^{2}
Reheating
Radiation
η_B^{exp}
0
−20
3
2
1
0
$\log_{10}(\phi\ /\ \mathrm{GeV})$
40
50
60
70
$\log(a/a_*)$
$\Delta L = 0$
$\Delta B \neq 0$
Sphalerons
Asymmetry production
LR Equilibration
L_L
Sphalerons
L_R

Backup slides

Summary and outlook

- We implement Dirac Leptogenesis to translate an asymmetry produced in an extended scalar sector during reheating to a BAU
- CP-violating inflaton decays source an asymmetry which is transferred to leptons via Yukawa couplings and converted to a baryonic asymmetry via weak sphalerons
- Only the asymmetry sequestered by neutrinos survives LR-equilibration
- A minimal realization extends the SM with a second doublet, a real singlet inflaton and three sterile neutrinos, all odd under a dark-sector Z_2
- Future testability analysis will study potentially observable ΔN_{eff} contributions and gravitational wave signals produced during reheating

Asymmetry from scalars

Scalar asymmetry → BAU

- CP-violation in the early universe:
  - K. R. S. Balaji, T. Biswas, R. H. Brandenberger, and D. London, "Dynamical CP violation in the early universe and leptogenesis," Phys. Rev. D 72 (2005) 056005
- Asymmetry from non-vanishing Higgs chemical potential:
  - G. Servant and S. Tulin, "Baryogenesis and DarkMatter through a Higgs Asymmetry," Phys. Rev. Lett.111 no. 15, (2013) 151601
  - S. Davidson, R. González Felipe, H. Serôdio, and J. P.Silva, "Baryogenesis through split Higgsogenesis," JHEP 11 (2013) 100
  - V. Keus and E. W. Kolb, "Baryogenesis from primordial CP violation," JHEP 07 (2025) 156
- Inflation-sourced asymmetry + sequestering-mediated leptogenesis:
  - N. D. Barrie and C. Han, "Affleck-Dine Dirac Leptogenesis," [arXiv:2402.15245]
- Reheating-sourced asymmetry + sequestering-mediated leptogenesis:
  - A. Ahmed, J. P. Garcés, and M. Lindner, "Primordial Dirac Leptogenesis," [arXiv:2509.xxxx]